DIE SET WITH POSITION SENSOR MOUNTED THEREON

Field of the Invention

The present invention relates to a die for bending a workpiece formed from sheet material. More particularly, the present invention relates to a die set comprising a female die having a sensor mounted therein for aligning the die set with a pre-marked location on the workpiece.

Background of the Invention

Brake presses are commonly used to bend workpieces formed from sheet material. For example, magnetic cores for electrical-power transformers typically comprise a plurality of thin sheets, or laminae, formed from a magnetic material such as textured silicon steel or

an amorphous alloy. Each lamina may be placed in a brake press, bent at multiple locations, and then stacked with and bound to other similarly-shaped laminae to form the magnetic core.

Close dimensional tolerances are usually imposed on magnetic cores formed in the above-noted manner. The minimum dimensional tolerances that can be imposed on particular magnetic core are limited by the precision with which its constituent laminae can be positioned during the bending process. In other words, each lamina must be precisely positioned in relation to the die set during the bending process to achieve close dimensional tolerances within the assembled magnetic core.

Conventional brake presses often comprise some type of mechanism that automatically positions the workpiece between the male and female dies of the die set. More specifically, the mechanism moves the workpiece until a predetermined location on the workpiece is substantially aligned with the opposing male and female dies. The male die is subsequently actuated, and punches a bend in the workpiece at or near the predetermined location.

The workpiece is usually positioned using a mechanical stop. The workpiece can also be positioned using one or more sensors, e.g., contact switches or optical devices. Mechanical stops and sensors provide an indication that an end of the workpiece is located at a predetermined distance from the die set. In other words, the brake press indirectly identifies the location at which a bend is to be formed based on the location of an end of the workpiece, and a predetermined relationship between the end of the workpiece and the desired location of the bend. The precision of the bending process is therefore affected by any inaccuracies associated with locating the end of the workpiece. The precision of the bending process is also affected by any inaccuracies in determining the relationship between the end of the workpiece and the desired location of the bend. These factors combine to limit the overall precision with which the noted bends can be placed on the workpiece.

Many manufacturers of electrical-power transformers face ongoing pressure from their customers to provide more efficient transformers. Increased efficiency can be attained by decreasing the manufacturing tolerances of the transformer's constituent elements. Hence, efficiency increases can be achieved by increasing the precision of the bending process performed the constituent laminae of the transformer's magnetic core. More particularly, the magnetic core can be manufactured to closer dimensional tolerances by increasing the

precision with which the die set is positioned relative to the laminae during the bending process. The precision with which conventional dies sets can be positioned relative to a workpiece is limited, however, as explained above. An ongoing need therefore exists for a die set that can be positioned more precisely than a conventional die set.

Summary of the Invention

A presently-preferred system for bending a workpiece having a marking at a predetermined location thereon comprises a male die having a substantially v-shaped end portion, a female die having a substantially v-shaped groove formed therein, and a sensor mounted on one of the male and female dies and being responsive to the marking when the marking is located at a predetermined position in relation to the sensor.

A presently-preferred die set for bending a workpiece having a reflective marking at a predetermined location on a surface thereof comprises a male die having a substantially v-shaped end portion, a female die having a substantially v-shaped groove formed in an end thereof and a bore extending inwardly from the v-shaped groove, and an optical sensor mounted in the bore and being adapted to generate a predetermined output when the sensor is in optical communication with the reflective marking.

A presently-preferred die set for bending a workpiece at a predetermined location thereon designated by a surface marking comprises a male die having a substantially v-shaped end portion, and a female die having a groove formed in an end portion thereof. The groove is adapted to at least partially receive the end portion of the male die, and is substantially centered about a centerline of the female die. The presently-preferred die set also comprises a sensor mounted in the female die and being substantially aligned with the centerline of the female die. The position sensor is adapted to respond to the surface marking when the surface marking is substantially aligned with the centerline of the female die.

A presently-preferred die set for bending a workpiece at a predetermined bending location marked with a material having a higher reflectivity than a surface of the workpiece comprises a male die having a substantially v-shaped end portion, and a female die having a substantially v-shaped groove formed in an end thereof. The presently-preferred die set also comprises an optical sensor mounted on one of the male and female dies. The optical sensor is adapted to generate an output having a first magnitude when the optical sensor is in optical

communication with the material, and the optical sensor is adapted to generate an output having a second magnitude when the optical sensor is in optical communication with the surface of the workpiece.

A presently-preferred method for bending a workpiece at a predetermined bending location comprises placing the workpiece on a brake press, moving a die set of the brake press until the predetermined bending location is positioned between a male and a female die of the die set, and punching the workpiece with the male die to form a bend therein.

A presently-preferred method for bending a workpiece at a predetermined location thereon designated by a surface marking comprises placing the workpiece in a brake press having a die set mounted thereon, moving one of the die set and the workpiece in relation to the other of the die set and the workpiece, locating the predetermined location using a sensor mounted on the die set and responsive to the surface marking, stopping movement of the one of the die set and the workpiece when the die set is substantially aligned with the predetermined location, and punching a bend in the workpiece using a male die of the die set.

Brief Description of the Drawings

The foregoing summary, as well as the following detailed description of a presently-preferred embodiment, is better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, the drawings show an embodiment that is presently preferred. The invention is not limited, however, to the specific instrumentalities disclosed in the drawings. In the drawings:

Fig. 1 is a perspective view of a presently-preferred die set;

Fig. 2 is a cross-sectional view of the die set shown in Fig. 1, and a lamina suitable for bending in the die set, taken along the line "A-A" of Fig. 1;

Fig. 3 is an exploded cross-sectional view of a female die and an optical sensor of the die set shown in Figs. 1 and 2, taken along the line "A-A" of Fig. 1;

Fig. 4 is a bottom view of the lamina shown in Fig. 2;

Fig. 5 is a cross-sectional view of the die set shown in Figs. 1 and 2 and the lamina shown in Figs. 2 and 4, depicting the lamina being bent by the die set, taken along the line "A-A" of Fig. 1; and

Fig. 6 is a diagrammatic side view of a brake press having the die set shown in Figs. 1, 2, and 5 mounted thereon.

Description of Preferred Embodiments

Figures 1-4 and 6 depict a presently-preferred embodiment of a die set 10 adapted for use in a brake press 100. The figures are each referenced to a common coordinate system 11 depicted therein. The die set 10 comprises a female die 12 and a male die (punch) 14. The die set 10 is adapted to bend a workpiece at one or more predetermined locations (these locations are hereinafter referred to as "bending locations"). The workpiece described herein is a lamina 20 for a magnetic core of an electrical power transformer. The lamina 20 is formed from a relatively thin, narrow strip of magnetic material such as textured silicon steel or an amorphous alloy. It should be noted that this particular type of workpiece is described for exemplary purposes only, as the die set 10 can be used to bend virtually any type of workpiece formed from sheet material.

The die set 10 further comprises an optical sensor 16 mounted in the female die 12 (see Figures 2 and 3). The sensor 16 is used to identify one or more marks 22 on the lamina 20 (see Figures 2 and 4). The mark 22 is applied at a desired bending location on the lamina 20 before the lamina 20 is placed in the brake press 100. It should be noted that the lamina 20 is depicted in the figures as having only one of the marks 22 thereon, for clarity. The die set 10 can be used in conjunction with laminae 20 having more than one mark 22 thereon, i.e., the lamina 20 can be bent at more than one location using the die set 10. Also, the size of the mark 22 is exaggerated in the figures, for clarity.

The male die 14 has a substantially v-shaped end portion 24 defined by a first angled surface 24a and a second angled surface 24b (see Figure 2). The first and second angled surfaces 24a, 24b are separated by an angle denoted by the symbol "α" in Figure 2. The value of "α" is dependent on the desired bending angle to be formed in the lamina 20. Hence, a particular value for "α" is not specified herein.

The female die 12 has a groove 26 formed in an end portion 28 thereof (see Figures 2 and 3). The groove 26 is defined by a first angled surface 28a, a second angled surface 28b, and a lower surface 28c that adjoins the first and second angled surfaces 28a, 28b. The groove 26 is substantially v-shaped. The first and second angled surfaces 28a, 28b are

separated by an angle denoted by the symbol "β" in Figure 2. The groove 26 and the end portion 24 of the male die 14 are complimentary. In other words, the angles β and α are approximately equal so that the end portion 24 is adapted to fit within the groove 26.

The female die 26 also includes a first end surface 28d that adjoins the first angled surface 28a, and a second end surface 28e that adjoins the second angled surface 28b. The first and second end surfaces 28d, 28e are substantially flat, and lie substantially perpendicular to a centerline C1 of the female die 12.

The female die 12 has a bore 29 formed therein (see Figure 3). The bore 29 extends inwardly (in the "-y" direction) from the lower surface 26c, along the centerline C1 of the female die 12. The bore 29 is located approximately half-way along the length ("x" dimension) of the female die 12 (see Figure 1). The sensor 16 is securely mounted within the bore 29 so that an end of the sensor 16 is substantially flush with the lower surface 26c. The sensor 16 may be secured within the groove 29 by a suitable means such as adhesive or a press fit.

The sensor 16 is an optical sensor of conventional design. For example, the sensor 16 may be a conventional photoreflector comprising a light-emitting diode and two light receiving regions. The sensor 16 is electrically coupled to an electronic control system (not shown) of the brake press 100. The sensor 16 is adapted to generate a responsive output when the mark 22 on the lamina 20 is positioned adjacent the groove 26 and is substantially aligned with the centerline C1 of the female die 12 (as shown in Figure 2). In other words, the sensor 16 provides the control system with an indication that a mark 22 is located directly above the female die 12. Further details relating to the sensor 16 are not necessary for an understanding of the presently-preferred embodiment and, therefore, are not presented herein. Furthermore, it should be noted that the presently-preferred embodiment is not limited to use with optical sensors; any suitable type of sensor can be used in lieu of the optical sensor 16.

The die set 10 is adapted for use with a brake press 100, as noted above. General details relating to the brake press 100 are as follows. It should be noted that the brake press 100 is described for illustrative purposes only. The presently-preferred die set can be used in conjunction with virtually any type of brake press.

The brake press 100 comprises a carriage assembly 102 (see Figure 6). The male and female dies 14, 12 are mounted on the carriage assembly 102. The male and female dies 14,

12 are spaced apart and substantially aligned in the vertical ("y") direction. In other words, the centerline C1 of the female die 12 is substantially coincident with a centerline C2 of the male die 14, and a gap exists between the male and female dies 14, 12 prior to the commencement of the bending process.

The carriage assembly 102 is suspended from a stationary support arm 103, and is adapted to translate in the "z" direction, i.e., in the direction denoted by the arrow 30 in Figure 6. The male and female dies 14, 12 are mechanically coupled to the carriage assembly 102 so that the male and female dies 14, 12 translate with the carriage assembly 102. In other words, movement of the carriage assembly 102 in the "z" direction causes a corresponding movement in each of the male and female dies 14, 12.

The male die 14 is mechanically coupled to a hydraulic ram 106 mounted on the carriage assembly 102. The hydraulic ram 106 is adapted to drive the male die 14 in the downward ("-y") direction, toward the female die 12. The carriage assembly 102 restrains the female die 12 from substantial movement in the vertical ("y") direction. The brake press 100 also comprises a stationary work table that supports the lamina 20 during the bending process (the work table is not depicted in the figures, for clarity).

Operational details concerning the die set 10 and the brake press 100 are as follows. A mark 22 is placed at each of the desired bending locations on the lamina 20 prior to the bending process, as noted above. The mark 22 is preferably formed by applying a bead of reflective material, e.g., reflective paint, across the width ("x" dimension) of the lamina 20 at each desired bending location.

The lamina 20 is subsequently placed on the work table, which supports the ends of the lamina 20. The male and female dies 14, 12 are positioned adjacent to, and on opposing sides of the lamina 20 when the lamina 20 is located on the work table, as shown in Figure 6.

The brake press 100, upon activation, positions the die set 10 in a position proximate a desired bending location on the lamina 20. More particularly, the electronic control system of the brake press activates a hydraulic drive mechanism 110 within the brake press 100. The drive mechanism 110 causes the carriage assembly 102 (and the die set 10) to translate in the "z" direction.

The light-emitting diode of the sensor 16 directs a concentrated beam of light at the adjacent surface of the lamina 20 as the carriage assembly 102 moves the female die 12

lengthwise along the lamina 20. The output signal of the sensor 16 is proportional to the intensity of the light energy that reaches the light-receiving regions of the sensor 16 (a substantial majority of this energy represents light that has been generated by the light-emitting diode and reflected back toward the sensor 16 by the surface of the lamina 20).

The magnitude of the output signal increases substantially when the sensor 16 (and the female die 12) reach a position adjacent, i.e., directly below, the mark 22, due to the relatively high reflectivity of the mark 22 in relation to the unmarked surface portions of the lamina 20. In other words, the magnitude of the output signal increases substantially when the mark 22 is positioned adjacent the groove 26 and is substantially aligned with the centerline C1 of the female die 12.

The electronic control system of the brake press 100 recognizes the increased magnitude of the output signal as an indication that the die set 10 is positioned adjacent a desired bending location on the lamina 20. The electronic control system, in response, immediately deactivates the drive mechanism 110. This action stops the die set 10 at a position adjacent the mark 22, i.e., at a position adjacent a desired bending location on the lamina 20.

The electronic control system subsequently activates the hydraulic ram 106. The hydraulic ram 106 drives the male die 14 downward (in the "-y" direction), toward the lamina 20 and the female die 12. The resulting contact between the male die 14, the lamina 20, and the female die 12 bends the lamina 20 at the desired bending location, as shown in Figure 5. The angle of the resulting bend is determined by the values of the respective angles α and β on the male and female dies 14, 12.

Positioning the die set 10 using the sensor 16 mounted in the female die 12 permits the die set 10 to positioned with a relatively high degree of precision in relation to a desired location on the lamina 20. More particularly, Applicants have developed a die set 10 that provides a direct indication of the relative positions of the die set 10 and a desired bending location on a workpiece such as the lamina 20. Hence, the use of the die set 10 eliminates the inaccuracies associated with conventional die sets which, as previously noted, are positioned based on an indirect determination of their position relative to the workpiece. Lower (more favorable) dimensional tolerances can therefore be achieved by forming components such as the lamina 20 using the die set 10 in lieu of a conventional die set.

It is to be understood that even though numerous characteristics and advantages of the present invention have been set forth in the foregoing description, together with details of the structure and function of the invention, the disclosure is illustrative only, and changes may be made in detail, especially in matters of shape, size, and arrangement of the parts, within the principles of the invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

For example, the sensor 16 can be mounted in the male die 14 instead of the female die 12. In addition, more than one of the sensors 16 can be mounted in the female die 12 or the male die 14. Furthermore, the die set 10 can be used in conjunction with a conventional press brake, i.e., with a press brake in which the workpiece, rather than the die set, is moved to prior to the bending process to align the die set and the desired bending location on the workpiece.